plied by a constant factor and diminished by the temperature of the dry-bulb thermometer multiplied by a certain factor." He found, however, that the factor which ought to be applied to the temperature of the wet thermometer is very nearly equal to 1 and further that the temperature of the dry thermometer enters with a factor that is not large. This leaves the equation $T_{min.} = t_1 - k$, or the wet-bulb temperature minus a constant (k) as indicated above.

The author says in closing, "* * * : Still there are some important factors left, which in a high degree influence the cooling of the ground and which need to be more thoroughly considered. I allude to the conductivity, heat capacity, and temperature gradient of the ground, which all are important causes of the local variations in minimum temperatures found at places situated near to one another. ' reat progress in our preditions of temperature changes of the ground will never be possible until these last-named problems are seriously attacked."

Dr. Franklin's investigations reviewed (above or on pp. 639–640) cover the points referred to by Dr. Ångström.—*J. Warren Smith.*

PROBLEMS ON THE RELATION BETWEEN WEATHER AND CROPS.

LLOYD D. VAUGHAN.

[Tiffin, Ohio, Nov. 24, 1920.]

For any crop of grain, fruit, or vegetables to come up to what is known to be its maximum yield, it must have whatever is correct in the way of soil conditions as regards fertility, drainage, etc., the proper care in planting and cultivation, and be favored by the kind of weather conditions which may happen to be suited to its requirements. The weather is by far the most variable and uncertain of the three and the study of its relation to crop growth presents a multitude of problems, the complete solution of which can not fail to be of considerable benefit to practical agriculture.

By the solution of these problems the relation between the weather and crops can be established on a quantitative basis, so that we may know the exact reason for any particular seasonal result for a certain crop and understand the connection between the coincident numerical values of crop growth or yield and weather conditions.

The following notes and list of problems will show that a great many observations and experiments of a special nature are required in this work if the results are to be of any real or permanent value. It would be advisable for this investigation to cover each locality where any of these conditions are different from those of another for it to include as many of these separate localities as possible.

1. *Temperature.*—(a) Observation of the daily range of temperature, or its variation in value during the full period of 24 hours. Data on the average daily temperature are required for this purpose rather than the instantaneous values noted but two or three times at certain hours during the day.

(b) Surface temperatures of the soil under variant conditions.

(c) Difference between soil and air temperatures.

(d) The amount of sunlight and radiation received and the presence of haze or cloudiness.

2. *Humidity.*—(a) Humidity, its relation to other weather factors and their combined influence on plant growth.

(b) The study of the sequence of changes in daily temperature, himidity, etc., from which predictions for minimum temperatures or frost conditions can be made.

3. *Rainfall.*—(a) Duration, or the amount falling within a certain time. This study is important in order to determine the effect of any quantity of rain on plant growth. It is very unlikely that 1 inch of rainfall in a period of one hour would be of as much benefit to a crop as would the same amount distributed over a three- to six-hour period.

In other words, the element of time as well as quantity should be taken into account and a record kept of this relation, so that by this or other means it may be possible to compare the total hours and inches of rainfall with the growth or yield of any crops.

(b) It is also important that a special note should be made of the time or part of the day when the precipitation occurs, and also of the soil conditions, temperature, sunshine or cloudiness, etc., immediately preceding, and for several hours following, any appreciable rainfall during the growing season.

(c) Temperature of catch.

(d) Evaporation rates, etc.

(e) Difference between soil and air moisture.

(f) The absorption of rainfall by soils and relative effect on plant growth.

4. *Effect of low temperatures on wheat and clover.*—There are three principal causes of the winter killing of these crops: (1) Smothering under an ice sheet, water, or packed and frozen snow; (2) heaving out by alternate freezing and thawing; (3) freezing by long-continued cold while having no protection.

Wheat seems to be able to withstand cold to temperatures possibly 10 or more degrees below freezing, but when these temperatures remain this low for any great length of time the plants, especially those near a crack in the soil, or which have their crown and roots exposed by the action of the wind and previous thawing, are likely to be frozen unless protected in some way.

A large total of snowfall during the dormant stage does not furnish a very reliable condition on which to depend as being the reason for the favorable outcome of this crop through the winter months.

The number of days showing the presence of snow enough to cover the plants completely may be a better indication, but as is sometimes the case the wheat may be well covered with snow through the major portion of the winter, when along toward spring there are a few days of thawing followed by a week or two of very cold weather, while the ground is nearly bare, which will discount the advantage gained through being protected all winter. The important point is that the ground should be covered with snow during the time that any conditions exist which may have an unfavorable effect on the winter survival of wheat, clover, and similar crops.

The kind of soil, the amount of moisture and organic matter contained therein, surface and under drainage, and the fall growth of these plants also have considerable to do with their survival through the winter season.

Data are needed in regard to the most favorable or unfavorable winter conditions for wheat, clover, various fruits, etc., as to the different ways in which they may be affected by the weather in combination with various modifications of the other factors named above. Also on the frequency of freezing and thawing, depth of freezing, the rapidity of change of temperature, and the extent of this variation.

5. *Correlation of weather and plant growth.*—(*a*) Comparison of yields of various crops with complete records of the weather conditions associated with them.

This study should cover as long a period and include as many sets of conditions as possible, in order to determine the normal values of both weather factors and crop yields and to learn the cause and effect of any departure from these normal values.

(*b*) Effect of weather conditions on the germination of seed, early growth, blossoming, formation of grain or fruit and the maturing of various farm crops.

More complete data are needed as to the effect of weather on the time of blossoming, formation of grain or fruit and the ripening of these different crops. Also in regard to the quality of grain, fruit, vegetables, etc., as related to the particular weather conditions experienced during the season in which they were grown.

(*c*) The daily, monthly, or seasonal distribution of temperature and precipitation as related to its effect on plant growth and the total heat, sunshine, and rainfall required to bring about a certain stage of growth and to produce and mature a full crop in the average time usually considered to be the growing season of any of the different crop plants.

(*d*) Physical and physiological studies of plants compared with weather. The combined influence and proportional effect of all the different factors of climate and weather on the development of any crop, as shown by continual observations of the rate of growth and extent of changes produced in the plant itself, from the time of planting until harvest.

6. The effect of temperature, sunshine, and precipitation on the activity of nitrogen bacteria and other soil organisms which are essential to plant growth.

7. The solubility of different carriers of nitrogen, phosphorus, potash, and other plant food elements, and the degree to which any plant may be able to utilize these elements, as dependent on the weather, or the temperature and moisture conditions of the soil during the season.

8. The effect of the weather on the propagation and natural control of insect pests and plant diseases. The damage done to crops by the chinch bug, Hessian fly, potato blight, various rusts, smut, and many other insects and diseases affecting fruit and grain crops depend to a great extent on the particular kind of weather experienced during certain periods of the year.

9. The influence of the weather on the prevalence and spread of animal diseases. There is already some evidence that many diseases of farm live stock, particularly those of a contagious nature, are subject to certain favorable or unfavorable weather conditions.

10. Mathematical analysis or correlation of the data collected on the relation of different meteorological factors to plant growth.

There are, no doubt, many other problems which could be added to this list, but it is intended only to point out the different groups of problems and the several lines of investigation which could be carried on by our experiment stations or other institutions where complete records are kept of the results of other investigations relating to agriculture.

Now the question may be asked, what practical value can be expected to be derived from the investigation of these problems, since the weather conditions which may cause either the success or failure of a crop must necessarily be a thing of the past before their effect can be studied.

One answer to this question is found in the fact that a clear knowledge of the effect of different weather conditions on crop plants at various stages of growth, may afford a fairly accurate idea of what effect any of these conditions might have on the subsequent development of a crop, and from this a better forecast can be made as to its final outcome and any dependent plans can therefore be made or changed accordingly.

If we should have the same range of temperature and receive the same amount of light, heat, and precipitation at the same particular time each year, and if this should occur year after year in a uniform annual cycle, then both experimental and practical agriculture would probably be reduced to simply a matter of difference in soils, seeds, fertilizers and culture, because then we should have some way of knowing about what results were to be expected each season.

But since the different weather factors vary greatly from one year to another, both as to quantity and quality and in their geographic and seasonal distribution, there is always a different combination of circumstances surrounding the growth of each year's crops.

These different sets of conditions may affect the growth of a plant in so many different ways that it is only by means of a well planned and extended series of careful field observations and the mathematical correlation of their results that we can expect to eliminate the uncertainity concerning the effect of any particular set of conditions on the life history of a plant and to apply these principles toward improving our systems of soil treatment, varieties, and the methods of culture and handling of any crop.

Perhaps no very radical improvement can be made, but it seems reasonable to expect that this knowledge should tend to increase the efficiency of our methods.

In any experimental fertility work, for instance, without accurate data in regard to the effect which various weather factors may have on soils and on plant growth, it is often quite difficult to determine just what part of the annual variations in the ratio between the results from two or more plots in a compatative test may be due to differences in soil treatment or to differences in the character of the weather conditions.

A certain kind, quantity, or combination of fertilizers, or a certain variety of grain or method of culture, may show an apparent advantage one year; while during the next year or two the seasonal conditions may be such as to cause the result to be entirely reversed and possibly another treatment or variety may return the most profit.

Or, as it is often the case, a crop of corn may not ear up well, or the wheat, oats, or clover may not grow or fill as it should, and again the potatoes or fruit may be subject to some unfavorable influence of the weather during the time of blossoming, ripening, or other critical periods of their growth.

The real cause of all these effects are usually only guessed at and several plausible explanations may be offered, but it would often be quite profitable to know the exact reason for them, as well as those which may cause a very good growth and yield.

It is well known that the compa ative merits of different varieties, cultural methods and fertilizer treatments can only be learned from the average of results covering possibly ten or more years of experiment, but it should be obvious that a more exact approximation could be ade if complete and reliable data were available conrning the relation of the weather to any irregular or nnual variations in these tests.

The success or failure of a year's work is dependent on the amount in which the crops may be favored by the weather, and although the farmer has no means of control over this element, there may be found several ways in which it is possible to take advantage of seemingly unfavorable conditions.

For this reason any facts which may be established through the investigation of these problems will help to give us a scientific knowledge of the different relations between weather and crops, and this knowledge put in workable form will enable agricultural experimenters, students, and farmers to clear up many things which are so little understood at this time, and thereby greatly improve the present status of agricultural practice.

THE INFLUENCE OF METEOROLOGICAL PHENOMENA ON VEGETATION.

Revue Scientifique, February, 1920, pp. 115-116.

Translated by Katharine Davis.

Dr. Azzi, of the University of Rome, has studied the relations existing between the critical periods of vegetation and meteorological phenomena. His method consists of observing at the same time the biological phenomena which dominate the life of plants and the meteorological phenomena which react on them with the greatest intensity. (Treatise presented by M. G. Wery to the Academy of Agriculture.)

Vegetation presents critical periods which are controlled by meteorological phenomena, rain, humidity (moisture), frost, heat, and dryness. Each period corresponds to a particular phase in the life of the plant; thus the critical period of vegetation of wheat with respect to rain is that, of variable duration, when this cereal requires, absolutely, a minimum of water. If rain does not fall at the precise time when the grain is in this critical period with respect to water, its development is hindered and the yield will be diminished.

In the same way for fruit trees, if the heat which is necessary for them in the corresponding critical period is less than they require, the crop will be decreased. (Leaf of Information of the Minister of Agriculture.)

Knowing the critical periods, it is necessary to know what are the mean epochs of the year when these occur for each one of the cultivated plants, epochs which vary with the region. One may then draw charts to which the author has given the name phenoscopic charts.

For each cultivated plant there are as many phenoscopic charts as there are critical periods and decisive meteorological factors; thus, there are four for grains relative to humidity (moisture); germination, earing, flowering, and maturity of grains.

Dryness being recognized as the determining cause for diminished return of grain crops in a particular zone, three methods are possible to agriculturists for offsetting this condition. (1) To avoid the phase of vegetation to which the critical period corresponds by modifying the time of seeding; (2) by modifying artificially the meteorological conditions during the critical period by irrigation if that is possible; and (3) to select grain in such a way as to obtain a variety which will resist the injurious meteorological phenomenon, dryness for example.

Phenoscopic charts may, then, assist to a knowledge of climatic conditions as geological charts assist to a knowledge of the soil and consequently of fertility.

THE INFLUENCE OF COLD IN STIMULATING THE GROWTH OF PLANTS.

By Frederick V. Coville.

[Abstracted from *Journal of Agricultural Research*, vol. 20, No. 2, Oct. 15, 1920.]

It is the general belief that dormancy in winter of our native trees and shrubs is brought about by cold weather, and that warm weather is of itself sufficient to start new growth in spring. Mr. Coville shows that both of these ideas are erroneous. From a number of very interesting and instructive experiments with blueberry plants under controlled conditions, it is shown that cold weather is not necessary for the establishment of complete dormancy and that after it is established the exposure of plants to ordinary growing temperatures does not suffice to start them into growth; also that plants will not resume normal growth in spring unless they have been subjected previously to a period of chilling. Finally, a theory is advanced to explain this paradoxical effect of cold in stimulating growth. The subject is presented in a series of numbered statements, with supporting evidence in each case.

Healthy blueberry plants were put into a greenhouse at the end of summer and kept at ordinary growing temperatures, but they gradually dropped their leaves and finally went into a condition of complete dormancy. The only difference between the behavior of the indoor and outdoor specimens was a tardiness of the former in assuming dormancy, probably due to a lack of injury to the foliage by freezing temperature.

Plants that were kept continuously warm during the winter started into growth much later in spring than those that were subjected to a period of chilling, while some that had been outdoors during the winter were brought into the greenhouse in early spring. The latter burst into leaf and flower luxuriantly, while the former remained completely dormant. In some cases, plants remained dormant a whole year under heat, light, and moisture conditions favorable for luxuriant growth. As a further test of the matter, some of the branches of a plant were extended through an opening in the greenhouse in one case, and in another the plant was placed just outside with some of the branches extending into the house. When spring came the outdoor branches, in both cases, put out leaves promptly and normally, but the interior branches remained dormant.

In explanation of these phenomena, Mr. Coville points out that the stimulating effect produced on dormant plants by cold is intimately associated with the transformation of stored starch into sugar. Stated in terms of simplicity, stripped of technical phraseology, the theory advanced in explanation of the formation of sugar during the process of chilling is that the starch grains stored in the cells of the plant are at first separated by the living and active cell membranes from the enzym that would transform the starch into sugar, but when the plant is chilled the vital activity of the cell membrane is weakened so that the enzym "leaks" through it, comes in contact with the starch, and turns it into sugar.